Software Enabled Control (SEC)

The objective of SEC is to co-develop advanced real-time control system algorithms and the software services and infrastructure necessary to implement them on distributed embedded processors in a robust and verifiable way

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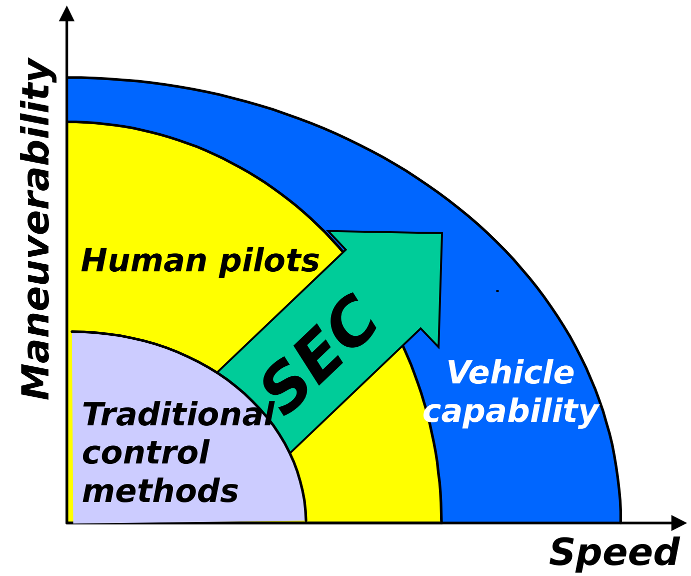
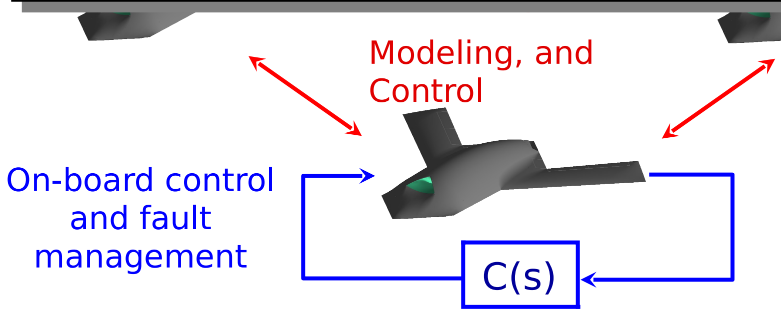
DARPA/IXO

Software-Enabled Control (SEC)

Control Systems for Vehicle and Mission Management:

- Design control systems for innovative vehicles
  - *UAVs, rotorcraft, fighters*
- Increase automation for extreme maneuvers
  - *Assured stability for flight mode transition*
- Improve disturbance rejection and fault tolerance
  - *Automatic control reconfiguration*
  - *Redundancy management*
- Provide reusable middleware for coordinated, embedded software control on multiple aircraft types
  - *Modernize flight control with adaptive, distributed computing*



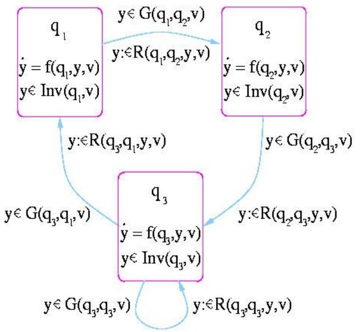


SEC provides control systems for innovative vehicles that exceed the capability of conventional flight controllers

Multiple levels of control:

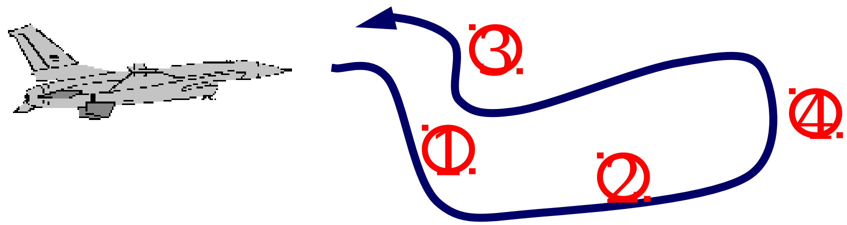
- *Vehicle management (including flight-critical systems)*
- *Mission management (including route planning)*
- *Multi-vehicle (e.g. automatic formation flight)*

Problems in Hybrid Control



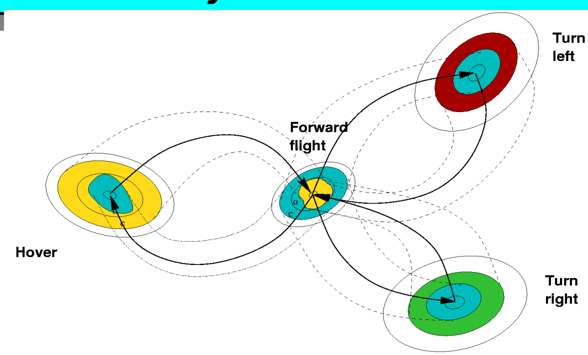
Hybrid Modeling and Formal Specifications

A formal representation and semantics must be established in order to process and reason about hybrid systems.



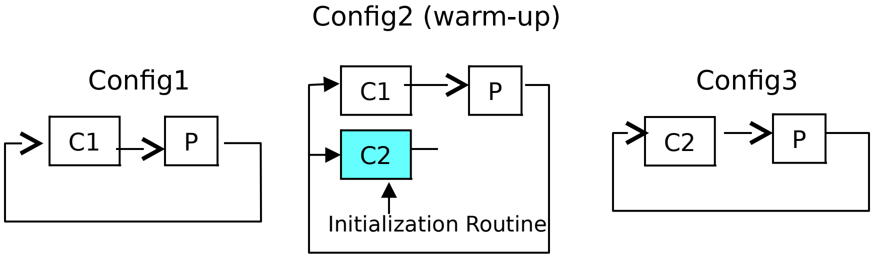
Hybrid Estimation and Tracking

*Unlike continuous-time estimation, both continuous variables and discrete events must be determined, and these depend on **asynchronous** events.*



Hybrid Stability and Reachability

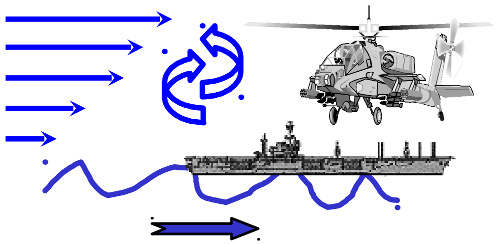
Stability in each and every mode does NOT imply system stability. We must transition between modes only when a "safe" set is reachable.



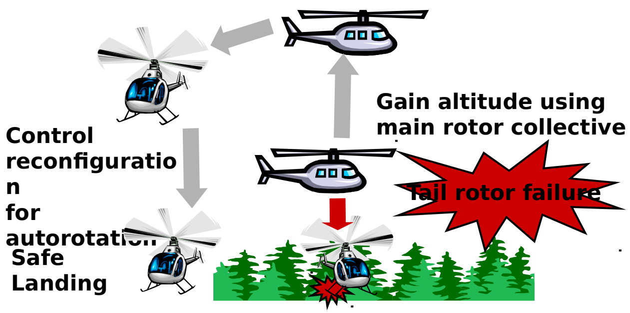
Mode Blending and Transient Management

Discrete jumps in control inputs can perturb or de-stabilize continuous nonlinear dynamics. Such transitions should be smoothed.

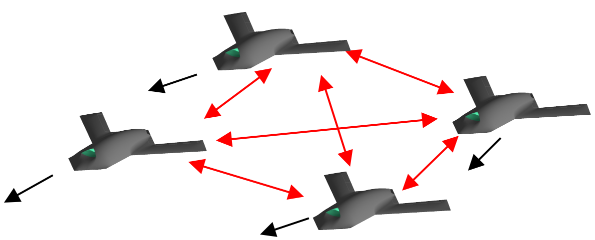
HOW: SEC Technologies



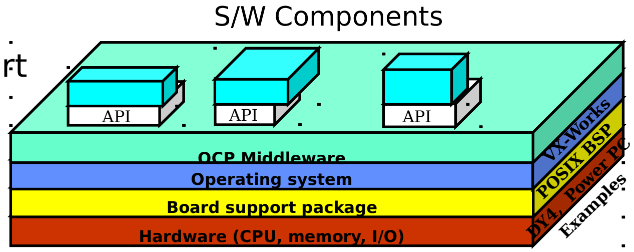
- ***Active State Models: Prediction & Assessment***
  - Dynamically exploit on-line system and environmental data to improve reference models
  - Predict effects over very large state and mode spaces
  - Rapidly assess damage



- ***On-Line Control Customization: Adaptation***
  - Enable precise mode transition
  - Support control re-parameterization and reconfiguration during operation due to environmental disturbances, interference, and damage
  - Accommodate dynamic coordination requirements



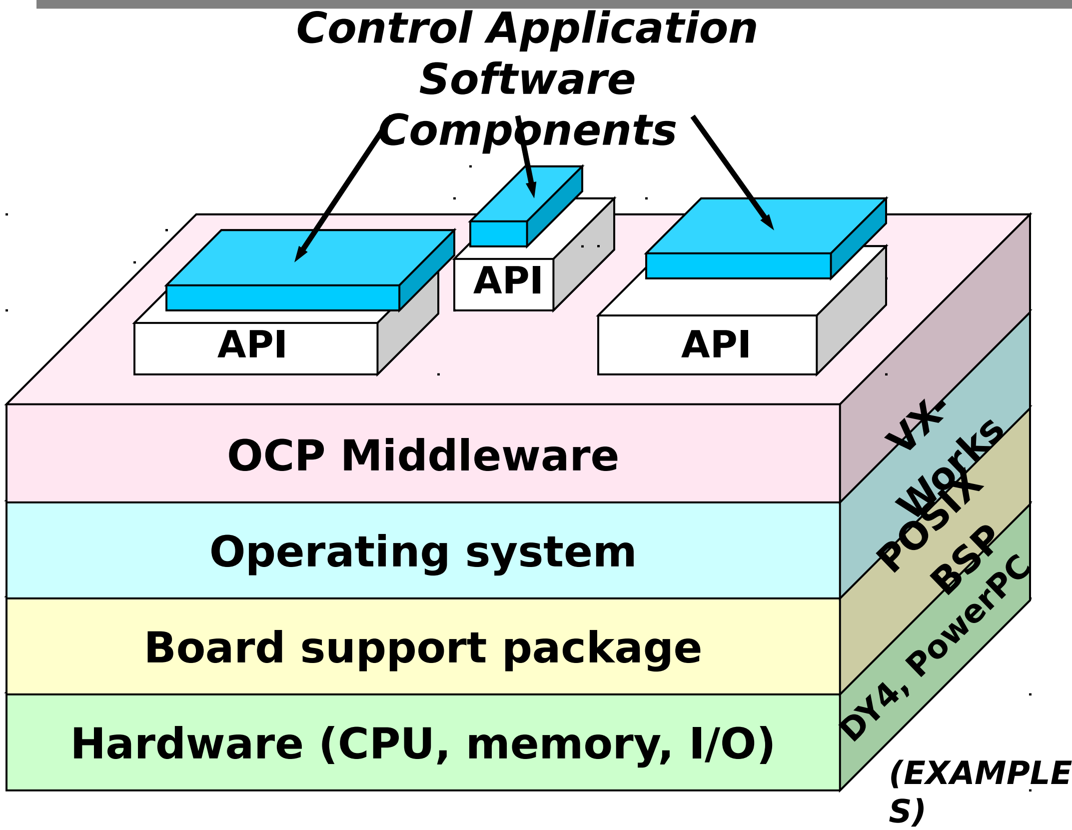
- ***Coordinated Multi-Modal Control***
  - Achieve global stability, maximize system and mission performance
  - Provide joint fault detection, isolation, and recovery
  - Enable distributed control implementation for physically separated components



- ***Open Control Platform (OCP): Software***
  - Provide reusable control middleware and tool support for building controllers from SEC technologies
  - Provide parametric open systems framework necessary to support SEC active state model, hybrid/coordinated, and adaptive multi-modal control
  - Provide flexible experimental platform for SEC control research and demonstration
- ***High Confidence Software Control Systems***
  - Assure safety and reliability under fault conditions

Open Control Platform (OCP)

The Open Control Platform (OCP) is a program task as well as the vehicle for contractor integration into demonstrations and experiments in flight control systems



API Examples:

Optimal Control
- *multi-criteria*
- *receding horizon*
- *distributed*

Hybrid Control
- *switching services*
- *blending*
- *planning*

Distributed Processing
- *distributed systems*
- *multi-vehicle*

Fault Management
- *detection and isolation*
- *reconfiguration*
- *error recovery*

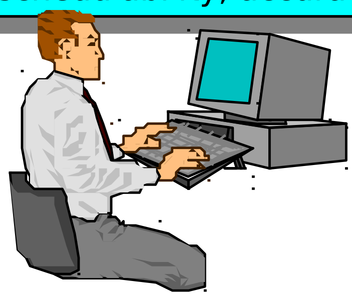
Active Models
- *model servers*
- *estimators*
- *multi-model management*

SEC Experiments and Metrics

Preliminary (thru 3QFY02)

Desktop Experiments: OCP integration and simulation, hardware-in-the-loop (HWIL).

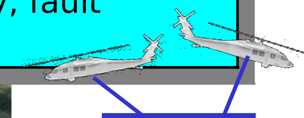
METRICS: Transition stability, loop speed, real-time schedulability, accuracy of model estimation.

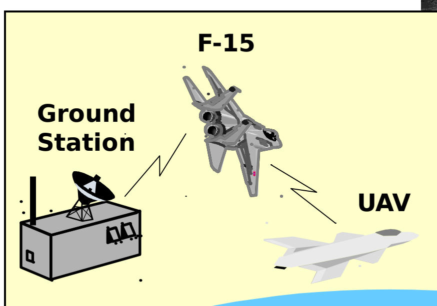


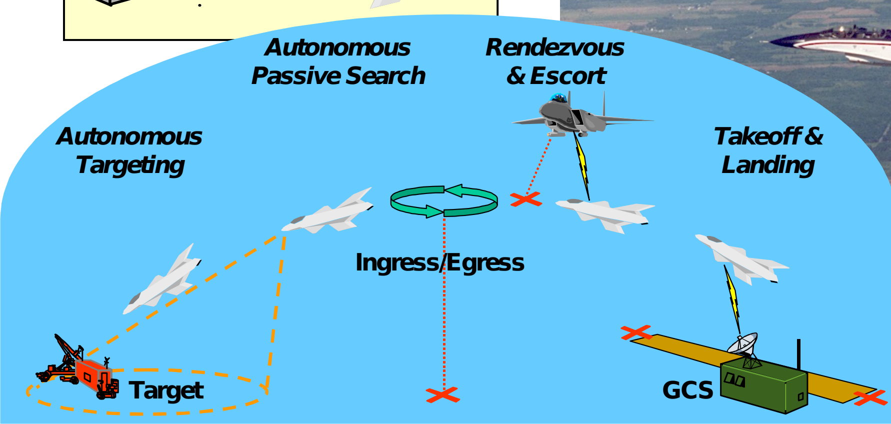
Mid-Term (4QFY02 thru 2QFY03)

Laboratory Vehicles (LAB-V): Fixed and rotary-wing, single and multi-vehicle scenarios, OCP on-board.

METRICS: Overall vehicle performance improvement (speed & maneuverability), adaptation speed, hybrid stability, fault detection & isolation.







Final Exam (2QFY04)

Full-scale flight tests: multiple UAVs and/or UCAV surrogates, control proxy from airborne C2 node (AWACS/MC2A/F15)

METRICS: Multi-vehicle tracking, fault recovery, on-line resource adaptation speed, vehicle performance, code verification time & effort.

SEC Tasks and Milestones

Active State Models
Honeywell
U Washington
Vanderbilt
OGI

Multi-Modal Control
Northrop Grumman
Draper Labs
Vanderbilt
Cal Tech
U Minnesota
UC Berkeley

On-Line Control Customization
UC Berkeley
Northrop Grumman
Stanford
U. Minnesota
Georgia Tech

High-Confidence Systems
Boeing
SRI
Honeywell
MIT
Cal Tech
Rockwell
Northrop Grumman

Prediction **Switching** **Adaptation** **Confidence**

Legacy Technology

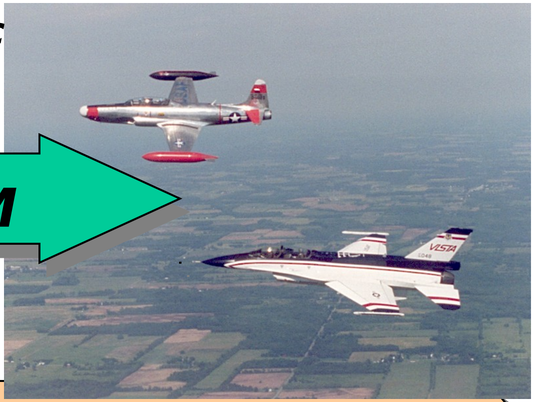
Real-Time Services

Bold Stroke

OPEN CONTROL PLATFORM

Boeing, GaTech, UC Berkeley, Honeywell

TRANSITION



Milestones

API for switching svcs.
Predictive models oper.
Hybrid multi-model svcs
Integrated model

Mode triggering defs.
CLF and LPV control
Hybrid stability, single sys.
Customization svcs.

Hybrid run-time svcs
High-level multi-mode API
Multi-mode run-time svcs.
Multi-vehicle hyb. control

Hybrid model checking
Formal specification lang.
Integrated fault mgt.
Sensor/act reconfig.

SEC Technology Transition